Cathodic Arc-Deposited Carbon Coatings Prolong Lifetime of Computer Hard Drives

Researchers of the Accelerator and Fusion Research Division at the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab.), IBM, and the University of California—Berkeley have found a way to shield disks and sliders (i.e., reader heads) with ultrathin coatings of diamondlike carbon that can survive repeated crash landings at 3,600 rpm. Typical high-quality commercial overcoats now in use are made of sputtered-on, hydrogenated carbon 12–15 nm thick. Higher data densities require reduced magnetic spacing between heads and disks, thus disk coatings must be thinner and made of even harder material, which sputtering cannot accomplish.

Simone Anders of Berkeley Lab. said, "What our team has done is to devise a filter so good that all our goals [of thin, flat, hard, macroparticle-free carbon] were fulfilled." The technique involves a magnetic coil that looks much like a Slinky toy, placed between the plasma source and the substrate to be coated. The fully ionized plasma is easily bent through this S-shaped magnetic field—effectively two fields at right angles—but the massive macroparticles of carbon cannot turn easily; they fly through the sides of the coil or pile up on its walls. A coil that has been used for some time is thickly coated with a dust of macroparticles near the plasma source, yet dust-free at the substrate end.

After perfecting the filtering method, Anders and her colleagues performed a series of endurance tests, pitting disks with cathodic arc-deposited carbon coatings against samples with sputtered, hydrogenated carbon coats. The researchers found that disks coated with cathodic arc carbon had a coefficient of friction half that of those coated with hydrogenated carbon and caused 20 times less wear on the slider. In additional studies, when a silicon wafer coated with cathodic arc carbon was examined at nanometer scale after repeated loading, it showed virtually no scratches.

As published in the October edition of *Data Storage* magazine, weighted sliders were repeatedly set down on spinning disks coated with hydrogenated carbon. As could be expected, uncoated sliders failed after only 7,500 cycles, but sliders coated with cathodic arc carbon endured more than 100,000 cycles, with no visible wear on the disk.

"For decades, tool manufacturers have put titanium nitride and other hard coatings on the cutting edges of their tools using a technique called cathodic arc deposition," said Anders. Unlike sputtering—in which the coating material is knocked off the cathode of the plasma source by ions, forming a plasma mixed with non-ionized (electrically neutral) atoms—cathodic arcs produce a fully ionized plasma of whatever material, including carbon, is used for the cathode. "Since the 1970s it has been known that carbon deposited this way is almost as hard as diamond," Anders said.

A fully ionized carbon plasma allows electrons and carbon nuclei to reassemble themselves as diamond, in a three-dimensional lattice in which each atom is bound to four others by electron pairs—a tetrahedral bond. By contrast, atoms in graphite are bound to only three other atoms, forming a much less stable configuration. By tuning the energy of the incoming carbon ions, the tetrahedral-bond content of the deposited film can be optimized; thus films have been made that, while technically amorphous, are 85% diamond.

Laser Beam System Measures Temperature of Galvanized Steel during Processing

An advanced temperature sensor originally developed to refine uranium for national defense programs by Oak Ridge National Laboratory (ORNL) is allowing producers of galvannealed steel to tell immediately if it is being processed correctly. Galvannealed steel is made by dipping a roll of steel in a liquid zinc bath at about 800°F (422.4°C). The steel strip then passes through a series of furnaces that raise the temperature to 1,000°F (532.4°C) During the process, iron atoms from the sheet move into the zinc coating to form a zinc-iron layer.

Conventional methods of measuring the temperature of the steel's surface have been unreliable because the zinc-covered surface has rapidly changing characteristics that complicate the ability to obtain an accurate measurement. Researchers at ORNL use fiber optics and pulses from a small ultraviolet laser to excite the phosphor. Light detectors measure the time it takes the fluorescence to decay, giving operators real-time data on surface temperature.

David Beshears of the Engineering Technology Division at ORNL said, "We use a low-power laser beam to read the surface after we've dusted it with a small amount of phosphor powder. Using short pulses of light from the laser, we can more accurately measure the temperature of the strip of galvannealed steel as it travels through the furnaces at up to 350 feet per minute."

According to Joe Vehec, director of the American Iron and Steel Institute, an early concern was whether the phosphor would damage the quality of the steel. Results of tests done by National Steel, the sponsoring steel company for the project, indicated no adverse effects on either the strip surface appearance or paintability, Vehec said.

The Institute of Materials Announces Awards for 1997

The Institute of Materials has announced its 1997 Awards for excellence in materials science and engineering. The recipients include

- **F. Kenneth Iverson** of Nucor Corporation who received the **Bessemer Gold Medal** for his vision and entrepreneurial skills in pioneering the application of thin slab casting and direct rolling for economic production of flat steel products and in creating the concept of the flat products mini mill;
- **K.A. Grosch**, consultant, who received the **Colwyn Medal** for his contributions to the understanding of rubber friction and abrasion;
- **G.C. Wood** of the Corrosion and Protection Centre, UMIST, who received the **Griffith Medal and Prize** for explaining fundamentally the formation, nature, and breakdown of protective films, produced by oxidation and corrosion on practically important metals and alloys, in gaseous, aqueous, and atmospheric environments; and
- **F.R.N. Nabarro** of the University of Witwatersrand, South Africa, who received the **Platinum Medal** for pioneering work on dislocation theory.

Haensel Named 1997 Draper Prize Recipient for Development of Clean Fuel

Vladimir Haensel has been selected as the 1997 Draper Prize laureate for developing Platforming—short for platinum reforming—which uses a platinum-based catalyst to efficiently convert petroleum into high-performance fuels. The trademarked process also generates large quantities of "aromatic hydrocarbons," which are the raw materials used in the manufacturing of plastics. The award, presented by the National Academy of Engineering (NAE), is the engineering profession's highest honor. This year the prize carries an honorarium of $450,000.

"The Platforming process has touched all of our lives in countless ways," said NAE President William A. Wulf. "Because of Platforming, today's fuel for cars, trucks, and practically all other forms of ground transportation is vastly more efficient, environmentally friendly, and easier and cheaper to produce than anyone thought possible just a few decades ago. And because of Platforming, we can rely on plastic for manufacturing our medical devices, automobiles, synthetics for clothing, and tape for video and audio recording."

In the late 1940s, while working for Universal Oil Products Co. (now called UOP) in Des Plaines, Illinois, Haensel sought to improve the way crude oil was converted into fuel. In 1947 Haensel developed a simple, efficient method that produced a remarkably high-grade fuel. His method also produced more gasoline from the same amount of petroleum. Platforming produces fewer emissions in the refining process, and because it generates significant amounts of hydrogen, it removes much of the sulfur and other contaminants from home heating oil, diesel fuel, and industrial fuel oil. The process also produces vast amounts of aromatic hydrocarbons, the raw materials used in the manufacturing of plastics. Previously, the plastics industry relied on the toxic processing of coal tar to obtain aromatic hydrocarbons.

The Draper Prize was established in

R&D Magazine Announces 100 Awards

The September 1997 issue of the trade journal *R&D Magazine* announced its 1997 awards for the top 100 technological achievements. Researchers and engineers at Oak Ridge National Laboratory (ORNL) received nine R&D Awards. Following is a partial list:

- **High Performance Storage System (HPSS)**, developed jointly with researchers from Lawrence Livermore, Los Alamos, and Sandia national laboratories and IBM Global Government Industry, is designed to manage enormous amounts of data produced and used in modern high-performance computing, data collection and analysis, and imaging and enterprise environments. The most innovative characteristic of the system is its scalability, meaning it can be customized to meet specific needs for data transfer rate, storage capacity, file size, the number of files, directories, and storage server nodes.
- **Chemicals from biologically derived succinic acid** was produced by fermenting glucose sugar from corn. The research, done jointly with scientists at Argonne National Laboratory, Pacific Northwest National Laboratory, National Renewable Energy Laboratory, and Applied CarboChemicals, led to a new microbe as part of a process that converts corn into a cost-efficient source of the chemicals used to make polymers, clothing fibers, paints, inks, food additives, and automobile bumpers among other products.
- **Electron-beam-curable cationic epoxy resins**, developed jointly with researchers at Oak Ridge Y-12 Plant and Oak Ridge Institute of Science and Education, dramatically reduces the processing time and the overall manufacturing costs for electron beam-curable cationic epoxy resins. Manufacturers use these resins for high-performance composites.
- **A methylated sol-gel sorbent**, developed jointly with researchers at Supelco Incorporated, detects airborne pollutants such as carcinogens and industrial effluents.
- **Metal compression forming**, developed in collaboration with researchers at Thompson Aluminum Casting Company of Cleveland, makes possible pore-free cast aluminum alloy components with properties comparable to those of forged parts at up to one-third the cost.
- **Vari-Wave, a microwave heating instrument** reduces curing time (from two hours to three minutes) of adhesives and polymers used in the production of circuit boards and components.
- **The metal ceramic composite crucible**, developed in collaboration with researchers of Blausch Precision Ceramics of Albany, is a carbon-free ceramic that contains an embedded metal colander and is used to melt metal by induction heating.

Researchers at Sandia National Laboratories received eight of the awards; following is a partial list:

- **The biological microcavity laser** is a handheld device that analyzes blood samples within minutes. The device, which uses many tiny fingers of laser light to image cells in a drop of blood placed in a small chamber, can be miniaturized to microchip size and would be field-portable. The apparatus eliminates the need to "stain" blood cells for better visibility, or send them to a distant laboratory for analysis, thus eliminating transportation costs and delays as well as potential for additional error.
- **The nonvolatile field effect transistor device** uses "clunky protons" that maintain screen memory by staying where they are. To create the memory-retentive chip, the key fabrication step is to bathe the hot microchip in hydrogen gas. The gas, permeating the chip, breaks up into single ions at defects in the silicon dioxide. The protons can roam only within the chip's central layer of silicon dioxide where they are trapped by two layers of silicon that sandwich the silicon dioxide. A positive low-voltage applied to one side of the silicon repels the protons to the far side of the silicon dioxide. A negative low-voltage applied to the silicon attracts the protons to the near side of the silicon dioxide. If the power is turned off, the protons stay where they are, retaining information until the machine is repowered.

Argonne National Laboratory received an award for the **mass spectroscopy of recoiled ion (MSRI) analyzer**, a device that lets scientists determine the surface composition and structure of thin films as they are growing.

The **ultrahigh gradient insulator (UHGI)**, a device developed by researchers at Lawrence Livermore National Laboratory and AlliedSignal Federal Manufacturing and Technologies plant in Kansas City, has, as its key technical advance, the use of extremely thin layers of conducting material between alternating layers of insulating material. In insulator tests of different materials, the UHGI, has demonstrated an approximately four-fold advantage for sustaining electrical voltages over current insulators. Using polycarbonate as an insulating material, the UHGI will support 200,000 volts of electricity for each centimeter of material, while current plastic insulators break down at 50,000 volts. Fused silica or glass insulators made with the UHGI technology will support 175,000 volts per centimeter; for alumina insulators, the UHGI will hold off 125,000 volts, compared with the 30,000 volts of current alumina devices.

Veeco Instruments Inc. has received an R&D award for its **ion beam deposition system**, used to deposit films for multilayer reflective extreme ultraviolet (EUV) masks. This system was co-developed with researchers from Lawrence Livermore National Laboratory.

1988 to recognize individuals whose outstanding engineering achievements have contributed to the well-being and freedom of all humanity. The biennial prize honors particularly those rare individuals who were able to take an idea, develop it, and put it into practice.

Lead Nanocrystals Embedded in Aluminum Come in Magic Sizes, Asymmetric Shapes

During research to explain why the properties of nanoscale particles differ dramatically from those of the same material in bulk, scientists at the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab.) and from the University of Copenhagen have discovered that tiny crystals of lead in an aluminum matrix come in only a few specific sizes and a handful of unusual shapes, and avoid others. The researchers chose to work with lead inclusions in aluminum partly because lead and aluminum do not readily dissolve in each other; boundaries between them remain sharp.

By means of vapor deposition the researchers laid a film of aluminum 100 nm thick on a silicon wafer, then implanted the lead with an ion beam. The silicon was shaved away until the alloy sample was thin enough to be transparent to their microscope's high-energy electron beam. The micrographs showed numerous nanometer-sized islands of lead in a shallow aluminum sea. The islands assumed a few different shapes and appeared in a range of discrete sizes.

Ulrich Dahmen, head of Berkeley Lab.'s National Center for Electron Microscopy (NCEM), said, "What surprised us was that some sizes were preferred, while others were avoided. With lead and aluminum, we found that the most preferred fit was nine for eleven."

As reported in *Physical Review Letters* **78**, (3), when the researchers analyzed their micrographs, two features became apparent. First, the "magic sizes" assumed by the lead inclusions corresponded to regularly repeating values of minimal strain energy. Some repeating ratios of lead to aluminum atoms cause less strain than others.

Second, many of the lead inclusions, especially the smaller ones, were asymmetrical. The equilibrium shape of a large inclusion (where interface energy is dominant) is a cuboctahedron, a symmetrical double pyramid with its six vertices lopped off. Small inclusions, however—where residual strain energy is dominant—are forced to assume magic sizes even at the cost of their equilibrium shape. In the micrographs they appear as parallelograms which have been truncated at one or more vertices.

By adopting asymmetrical shapes, small magic-size inclusions can maintain perfectly flat interfaces with the host matrix. This in turn suggests that small inclusions have to be superheated to melt because more heat energy is needed to overcome the constraint at the perfect interface of an asymmetrical, magic-size inclusion than at the imperfect interface of a symmetrical inclusion.

Modified Metallocene Catalyst Simplifies Manufacture of Alpha-Olefins

By modifying the structure of a class of chemical catalysts known as metallocenes, chemists at the University of Rochester have uncovered a much simpler way than has been previously used to make the material that forms the basis of a wide range of consumer goods, including soaps, detergents, oils, and plastics.

Scientists making alpha-olefins typically need temperatures of 400–500°F (202.4–257.4°C) and pressures of 100–200 atm because they use aluminum or nickel catalysts, which require extreme pressures and temperatures to work. Guillermo Bazan, associate professor of chemistry, said, "It's costly to attain these conditions and to build the reactors needed to make alpha-olefins with aluminum or nickel catalysts."

Bazan's modified metallocene catalyst, bis(ethoxyboratabenzene) zirconium dichloride (BEZD), is capable of churning out alpha-olefins at only one atmosphere of pressure and temperatures just slightly above room temperature. BEZD strings ethylene molecules end-to-end to form alpha-olefins just as quickly as traditional aluminum and nickel catalysts, Bazan said. It also gives scientists precise control over how long the chains grow. Under varying pressure, BEZD can produce carbon chains ranging from ethylene dimers, with four carbons atoms, up to polymers containing many thousands.

As published in the October 1 issue of the *Journal of the American Chemical Society*, the catalyst molecule Bazan created resembles metallocenes both structurally and electronically. While metallocenes typically include two five-carbon rings bracketing a single atom of the transition metal zirconium, BEZD features six-membered rings containing five carbons and an added boron atom to regulate zirconium's reactivity. The molecules that grow in the presence of the two catalysts, however, differ dramatically. While traditional metallocenes yield long polymers of ethylene, BEZD leads to alpha-olefins, which are much shorter, versatile, and easily modified organic chains.

Rick Kemp, a senior research scientist at the Union Carbide Corporation and an

Special *Science* Issue Describes Materials Research with Focus on Microstructural Engineering of Materials

The August 29th issue of *Science*, a journal published by the American Association for the Advancement of Science (AAAS), features four news reports on materials research followed by six articles on various aspects of materials. With particle physicists' annoying discovery of visible synchrotron radiation in 1947, a new level of materials research developed. Four news reports describe materials research projects that use synchrotron facilities (the European Synchrotron Radiation Facility (ESRF) in Grenoble, France; the Advanced Photon Source at Argonne National Laboratory in Illinois, U.S.A.; and Spring-8 in Nishi-Harima, Japan) to address studies in materials properties and materials issues in biology and earth sciences.

The issue then offers six articles. H.W. Zandbergen, S.J. Andersen, and J. Jansen from Delft University of Technology, The Netherlands, have determined the precipitate composition of an aluminum-magnesium-silicon alloy as Mg_5Si_6. M. Muthukumar (University of Massachusetts), C.K. Ober (Cornell University), and E.L. Thomas (Massachusetts Institute of Technology) summarize self-organizing polymeric materials that make use of competing molecular interactions. G. Decher from the Université Louis Pasteur and CNRS describes developments toward multilayered polymeric composites. G.B. Olson from Northwestern University discusses the design of materials as interactive systems. Samuel I. Stupp and P.V. Braun from the University of Illinois at Urbana-Champaign discuss how organic molecules can alter inorganic microstructures, using biomaterials, ceramics, and semiconductors as examples. The final article by Z-R. Chen and J.A. Kornfield of the California Institute of Technology and S.D. Smith, J.T. Grothaus, and M.M. Satkowski of Procter and Gamble report on dramatic changes in polymeric materials in response to dynamic processes such as flow.

expert on alpha-olefins, said, "There are a million and one uses for alpha-olefins. In addition to serving as precursors for detergents, synthetic lubricants, and octane enhancers, they're used to produce a significant fraction of the 150 billion pounds of polyethylene and polypropylene produced each year—plastics found in products ranging from ice cube trays to textiles to bottle caps to trash bags." By working with chemical companies, Bazan hopes to determine within the next year whether BEZD is an industrially feasible means of producing alpha-olefins.

Protein Chaperone Escorts Copper in Cells

Heavy metal ions, which are toxic to cells, are required in tiny amounts in a few key components of the cell's biochemical machinery. Researchers at Northwestern University, Johns Hopkins University, and the University of Michigan showed that a protein, which floats freely inside the cell, picks up copper in its most highly reactive chemical state from a "pump" protein that is embedded in the cell's wall. The protein encases copper, then transports the copper to a few enzymes that use it to catalyze vital biochemical reactions. The existence of the copper chaperone suggests that other essential metals, such as zinc and iron, may have chaperones that function similarly.

As reported in the October 31 issue of *Science*, the researchers studied the copper chaperone protein from yeast, which provides a good model of copper metabolism in animal cells. They cloned the gene and put it into bacteria, which made large quantities of the protein for physical study. The human copper chaperones (there are known to be more than one) are required to transport copper, but diseases related to their malfunction have not yet been identified. According to Thomas O'Halloran, professor of chemistry at Northwestern, the protein that malfunctions in Wilson and Menkes' diseases normally receives copper from a copper chaperone and has a very similar design to it.

Geneticist Valeria Culotta and her coworkers at Johns Hopkins, SuJu Lin and Paul Schmidt, cloned the copper chaperone protein gene in yeast and proved that the chaperone actually touches the protein to which it transfers the copper.

Spectroscopist James Penner-Hahn of the University of Michigan and his student Katrina Peariso used synchrotron radiation to probe the chemical state of copper within the chaperone protein. Robert Pufahl, Chris Singer, and Chris Fahrni worked with O'Halloran at Northwestern to isolate and characterize the chaperone protein molecule itself.

O'Halloran said, "The cell needs copper and a few other heavy metals for essential enzymes, but when they're not in an enzyme's active site they can destroy cellular components."

According to O'Halloran, studying the function of the copper chaperone also should help scientists understand how other toxic metals are handled within the cell. He said, "Mercury and silver are not essential to yeast or humans and therefore not likely to have chaperones, but they might piggyback on the other metals' chaperones and wreak havoc on the cell."

Carbon Nanotubes Bent Repeatably with No Catastrophic Failure

Carbon nanotubes, discovered six years ago by Japanese scientist Sumio Iijima, are proving to be stiffer and stronger than any other known substance. They are created by arcing electricity between two sticks of carbon. Researchers at the University of North Carolina at Chapel Hill used a computer-linked microscope to bend and record properties of carbon nanotubes.

Michael R. Falvo, a doctoral student working under the direction of Richard Superfine, assistant professor of physics and astronomy at the university, said, "What we have found is that under large strains, the [carbon nanotubes] have the extraordinary property of being one of the stiffest materials known, while also being able to bend without breaking and then be bent back into their original shape."

As reported in the October 9 issue of *Nature*, Superfine's team used a device they invented, called the nanomanipulator, to bend the nanotubes, then measure the curvature of the bends. They also studied the tubes' buckling behavior. Previously, experimental evidence on the nature of bent nanotubes has been based on finding nanotubes bent during the deposition process or because of substrate distortion.

Falvo said, "We found that most of the bending was reversible, and that's exciting because it was not known before. Even after repeated bending and straightening of the nanotubes, they did not break. In fact, we have never observed a tube fail after repeated bending."

The nanomanipulator combines a commercially available atomic force microscope with a force-feedback virtual reality system. The former employs an atomically small probe capable of bending and otherwise manipulating molecule-sized particles. The latter allows the scientists to see and feel a representation of the surface a million times larger than its actual size. The experiments indicate that carbon nanotubes are significantly stronger than carbon fibers and hundreds of times stronger than steel.

Spriggs Honored for Work on Ceramic Processing

The Organizing Committee of the IV International Symposium on SHS (self-propagating high-temperature synthesis) has awarded the Medal of Honor to Richard M. Spriggs for his "important contribution to worldwide progress in SHS on the occasion of the 30th anniversary of SHS." Spriggs is director of the New York Center for Advanced Ceramic Technology, the John F. McMahon Professor of Ceramic Engineering, and the director of the Office of Sponsored Programs at the NYS College of Ceramics at Alfred University.

Ultrasonic Waves Used to Detect Corrosion in Insulated and Uninsulated Pipes

Engineers at The Pennsylvania State University have developed a pipe comb system, called a pipe comb guided wave transducer, that uses ultrasonic waves to detect and measure corrosion and wall thinning in insulated and non-insulated pipes. The device, which is being patented, can inspect 40 feet of pipe or more at one time without being moved and offers 100% cross-sectional coverage. It can also inspect water-filled and immersed pipes as well as work through welds, and around bends, elbows, and corners with little loss in sensitivity.

Pipes tapped at one location will carry or guide the sound wave so that the tapping can be heard at other locations along its length. Inaudible, ultrasonic waves can be guided along pipes in this way as well. As reported in *Materials Evaluation*, in the pipe comb system, the sender and receiver are incorporated in a series of thin plates spaced like the teeth on a comb. The pipe comb system can either be wrapped around the pipe or, in the case of very large diameter pipes, can be laid on the top. Even though the device lies only on the top of the pipe, it can still inspect the bottom at a length at least 40 feet downstream.

Insulated pipes can be prepared for inspection by removing a small band of insulation about every 40 feet. Field tests conducted on piping under insulation in both a laboratory and a chemical processing facility show that the system can detect corrosion and measure wall thicknesses across a wide range of pipe sizes and insulation types.

The device is based on techniques that Joseph L. Rose, the Paul Morrow Professor in Design and Manufacturing in the College of Engineering, developed for a probe designed to inspect small bore tubing in nuclear and fossil fuel steam generators.

Swindeman Awarded 1997 Pressure Vessel and Piping Medal

Robert W. Swindeman of Oak Ridge National Laboratory (ORNL) has recently been awarded the 1997 Pressure Vessel and Piping Medal by the American Society of Mechanical Engineers. The medal is presented annually to one person for outstanding contributions in the field of pressure vessel piping technology.

Swindeman, who received bachelor's and master's degrees in metallurgical engineering from the University of Notre Dame, has contributed almost 40 years to the knowledge of elevated temperature behavior of piping and pressure vessel materials. During the past 12 years, he has assisted in the management of alloy evaluation programs for power plants and the research and development of new pressure vessel piping materials for industrial applications.

Solar Cell Purified with Phosphorus Doping and Aluminum Sintering

To improve solar cell efficiency at low costs, Scott McHugo of the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab.) has identified the material hindering the cells' output of electric current. Solar cells have a junction between *p*-type silicon and an *n*-type layer such as silicon doped with diffused-in phosphorus. He said, "When sunlight is absorbed, it frees electrons which start migrating in a random-walk fashion toward that junction. If the electrons make it to the junction, they contribute to the cell's output of electric current. Often, however, before they reach the junction they recombine at specific sites in the crystal," and thus cannot contribute to current output.

McHugo looked at a map of a silicon wafer in which sites of high recombination showed up as dark regions. Earlier, researchers had shown that these occurred not primarily at grain boundaries in the polycrystalline material, as might be expected, but more often at dislocations in the crystal; yet, the dislocations were not the problem. Using heat treatment, McHugo performed electrical measurements to investigate the material at the dislocations, finding that they were decorated with iron.

Using an x-ray fluorescence microprobe beamline, McHugo was able to align the resulting x-ray fluorescence spectra with maps of the defects made with a scanning electron microscope, comparing defects and impurities directly. "That's when I found that not only iron but copper and nickel were also concentrated in these high-recombination sites."

Metal from valves, couplings, and other machinery can contaminate solar cells as they are grown from molten silicon, cut into wafers, and finished by adding dopants and attaching contacts. In an industry with a narrow profit margin, where cheap polycrystalline silicon must be used instead of easy-to-purify but far more costly single-crystal silicon, rigorous cleanliness at every step would be too expensive.

However, when purifying solar cells, cleanliness is not the only variable. Doping with phosphorus, as well as sintering aluminum contacts onto the wafers, both help in gettering the silicon. By adjusting time and temperature, these standard processes could be optimized to do a better job. As reported in the October 1997 issue of *Applied Physics Letters,* McHugo has shown that briefly annealing the finished solar cell at high temperatures is enough to remove copper and nickel precipitates of moderate size, although dissolved copper and nickel or very small precipitates of these metals may remain.

Arden Bement to Receive National Materials Advancement Award

The National Materials Advancement Award will be presented by the Federation of Materials Societies to Arden L. Bement, Jr. of Purdue University at a reception at the National Press Club in Washington, DC on December 9. Bement is being honored "for leadership in fostering cooperation among the industrial, governmental and academic sectors of the materials community, and for effective presentation of the promise of materials to government and the public at large." The award recognizes individuals who have demonstrated outstanding capabilities in advancing the effective and economic use of materials and the multidisciplinary field of materials science and engineering generally, and who contribute to the application of the materials profession to national problems and policy.

Bement began his career in 1954 with the Hanford Laboratories where he became manager of the Fuels and Materials Department. In 1970 he assumed his first academic post as a full professor of nuclear materials and materials science and engineering at the Massachusetts Institute of Technology. This was followed by government service as director of the Materials Science Office at the Defense Advanced Research Projects Agency (DARPA) (1976–1979) and Deputy Under Secretary of Defense for Research and Engineering (1979–1980). In 1980, Bement began his second career in industry as vice president of TRW, and in 1993 joined the faculty at Purdue as the Basil F. Turner Distinguished Professor.

In the mid-1980s, Bement chaired the National Materials Advisory Board, overseeing the study "Materials Science and Engineering for the 1990s," which has had broad impacts on the interactions of all sectors of the field. Bement is a former chair of the Statutory Visiting Committee of the National Institute of Standards and Technology, a former member of the Board of Overseers of the Malcolm Baldridge National Quality Award of the Department of Commerce, a former chair of the National Materials Advisory Board, and a former chair of the Commission on Engineering and Technical Systems of the National Research Council. He received his PhD degree in metallurgical engineering in 1963 from the University of Michigan. □

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